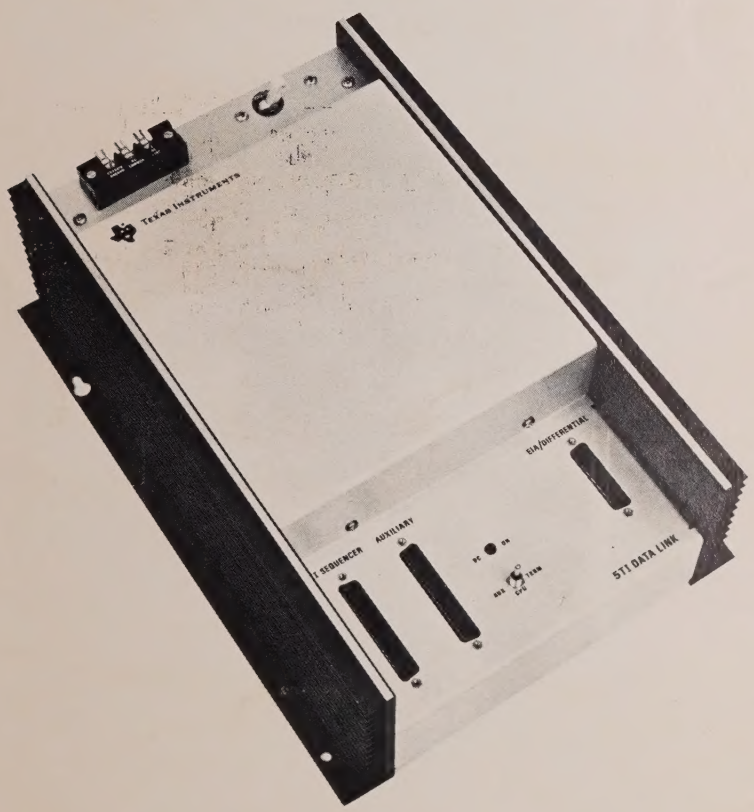
TEXAS INSTRUMENTS

5TI 3100
DATA LINK
INSTALLATION AND
OPERATION MANUAL



5TI 3100
DATA LINK

INSTALLATION AND
OPERATION MANUAL

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SECTION I
INSTALLATION

1.1 Dimensions

Length	13.2" (33.5CM)
Width	9.4" (23.9CM)
Depth	4.2" (10.7CM)

1.2 Mounting Dimensions

Appendix I is an envelope drawing showing the mounting dimensions for the DATA LINK.

1.3 Power Requirements

Voltage	85-132 VAC
or	176-253 VAC*
Frequency	47-63 HZ
Input Current	0.5 AMPS Max.

1.4 Environmental Requirements

Temperature	0-60°C
Humidity	0-95% R.H. (Noncondensing)

1.5 Orientation

It is recommended that the DATA LINK be mounted in a position such that the black side panels (heat sinks) have a vertical orientation.

*Consult Factory

1.6 Connections

There are four connections possible to the DATA LINK. (See adjoining page.)

1.6.1 AC Power

Is connected to the three terminal connector at the same end of the unit as the circuit breaker switch.

1.6.2 5TI Sequencer

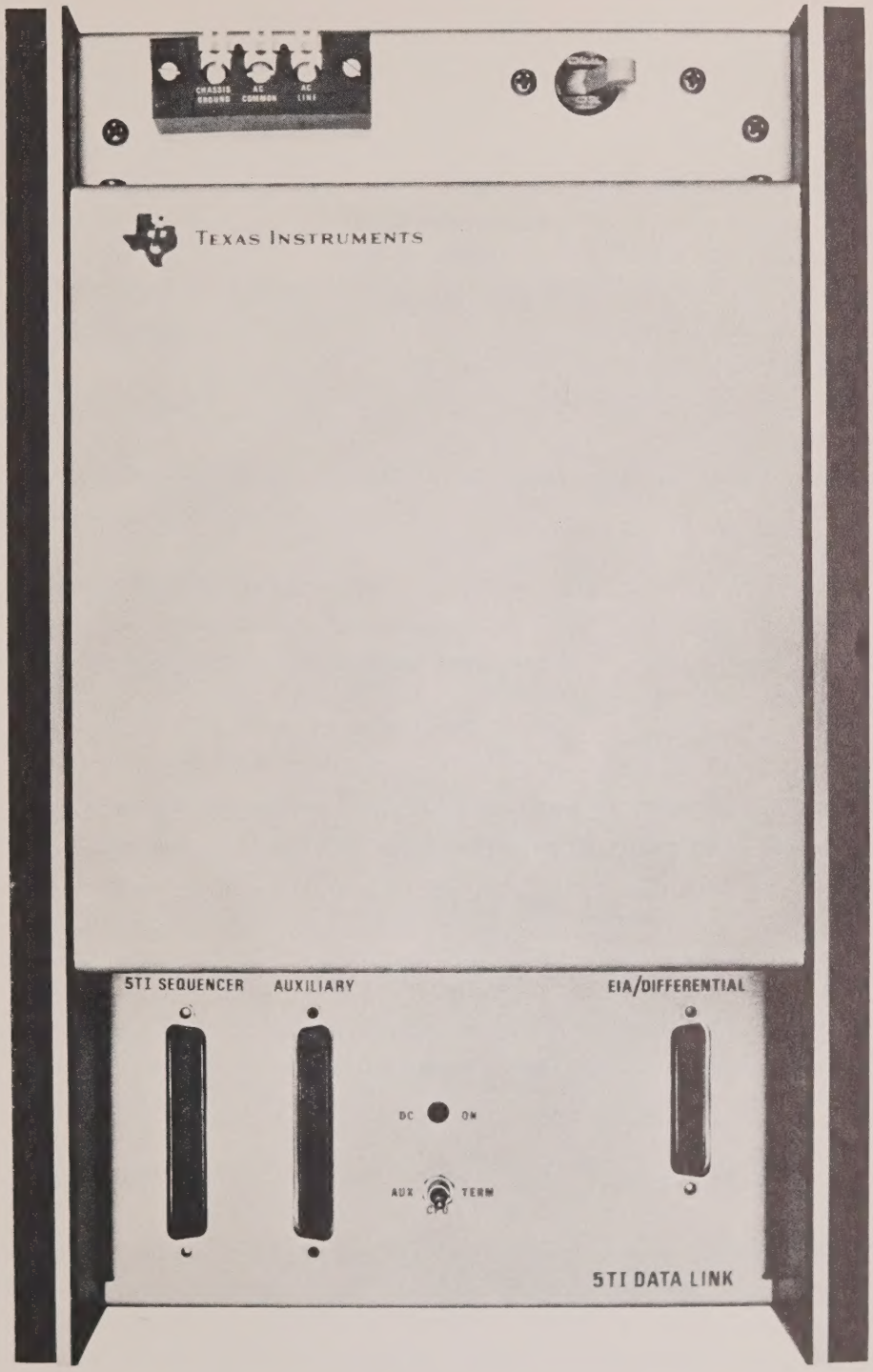
Provides the interface to the 5TI sequencer. A two foot long 37 conductor cable is provided for this purpose.

1.6.3 Auxiliary

Provides access to the 5TI memory using a R/W Programmer, PROM Programmer, or TCAM. The AUXILIARY connector on the sequencer, which is normally used for this purpose, would now be occupied by the DATA LINK.

1.6.4 EIA/Differential Line

Provides the interface to the computer or terminal. It is a 25 pin female connector (Cinch or Cannon DB-19604-433). The mating connector must be a 25 pin male connector (Cinch or Cannon DB-19604-432, or Hood DB-51226-1) with the pin assignments shown in the table in Appendix B.



5TI 3100 DATA LINK

SECTION II
OPERATION

2.1 Controls and Indicators

2.1.1 Circuit Breaker

The DATA LINK contains a 0.5 AMP circuit breaker to switch AC power. The DATA LINK software will re-initialize on power up.

2.1.2 AUX/CPU/TERMINAL Switch

Allows selection of operating configuration as follows:

2.1.3 AUX

Permits use of R/W Programmer, PROM Programmer, or TCAM through the auxiliary connector. Communication through the EIA/Differential connector is limited to reading sequencer only.

2.1.4 CPU

Permits use of EIA/Differential connector to communicate with a computer. Access to the 5TI sequencer memory through the auxiliary connector is still possible, however computer communication will have priority.

2.1.5 TERMINAL

Also permits use of both EIA/Differential and auxiliary connectors, with the EIA/Differential port having priority. However, it has three additional functions. First, it selects a second baud rate as defined in "Selection of Options". Second, it activates the Terminal Option software on DATA LINKS so equipped. Third, it automatically selects asynchronous protocol, and single point operation.

2.1.6 DC ON Indicator

Shows presence of DC power in the DATA LINK and operation of the self-diagnostic feature. (See Section 2.9.2.)

2.2 Selection of Options

There are two blocks of switches on the logic board behind the back access panel. One is a block of seven switches which are used for determining multipoint address, differential line vs. EIA interface, one or two stop bits in asynchronous transmission, and synchronous or asynchronous protocol. The second block has eight switches and is used to select baud rates for the "CPU" and "TERMINAL" positions of the three position switch on the front panel.

Appendix C has tables showing the various switch settings necessary to achieve the desired options.

2.3 Communication Format

Communication between the DATA LINK and user's device must be in 7 bit ASCII code plus parity. Appendix D shows the ASCII code set. Using this language, the user device must be able to block information for transmission. The block will have different characteristics depending upon the protocol used. All blocks, regardless of protocol used (asynchronous, synchronous, or multipoint), will be of three types; header blocks, acknowledge blocks, and data blocks.

2.3.1 Header Blocks

Header blocks are used to initiate transmission from the user's device and should be composed of the following types of characters:

a. SOH – Start of Header – 1 character.

b. Read/Write Command – Determines whether to read memory or image register, or write into memory – 1 character.

c. Starting Address – Four digit starting address of first 5TI word to be transferred – 4 characters.

d. Number of 5TI Words to be Transferred – Four digit number of 5TI words to be read from, or written into the sequencer's memory.

e. EOT or ETB – End Of Transmission, or End of Transmitted Block. Signals either the end of transmission from this device (as might be true in a "read"), or just the end of the block, if more information is to be transmitted (as might be true in a "write").

In addition, depending on the protocol, other characters (such as "SYNC" characters) may be added, as required.

2.3.2 Acknowledge Blocks

Acknowledge blocks are used after each transmission to confirm receipt of the information sent. They typically contain two types of characters.

a. ACK or NAK – Acknowledges, negatively or positively, the receipt of information.

b. Ø or 1 – This character follows the "ACK" character. Each transmitting device should alternate, ACKØ, ACK1, ACKØ, etc., beginning with ACKØ.

In addition, depending on the protocol, other characters (such as "SYNC" characters) may be added as required.

2.3.3 Data Blocks

Data blocks contain the actual information to be transferred. Clearly, they can be sent by both the user's device and the DATA LINK, and typically contain three types of characters:

a. STX – Start of transmission

b. Data

c. EOT or ETB

As before, other characters may be required, depending on the protocol being used.

In a multipoint configuration, two characters should be added to the front of the header block:

a. EOT

b. Multipoint Address

The possible allowed addresses are shown in Appendix C: Option selection diagrams.

Examples of the various blocks and protocols are shown in Appendix F.

2.3.4 NAKPAC Block

This is an exclusive feature used in diagnosing communication format caused errors such as illegal or missing characters, invalid commands, transfer errors, etc. It operates as follows:

If there are no errors in the transmission to the DATA LINK, it will respond with an "ACK" as explained in the section on programming.

If the transmission contains an overrun, parity, framing error, or bad LRC, the DATA LINK will respond with a "NAK". Typical causes of these errors are:

a. Overrun – Caused by sending a data block to the DATA LINK before the DATA LINK has had time to "ACK" the last block sent.

b. Framing – Can be caused by incorrectly selecting the number of stop bits in asynchronous transmission (async only).

c. Parity – Caused by sending other than *odd* parity to the DATA LINK.

d. Bad LRC – Calculated LRC and received LRC do not match (sync only).

Any other transmission errors will be indicated by a block which will be transmitted by the DATA LINK. This block will be composed of the following characters:

a. STX

b. ?

c. } Two digit number.
d. }

e. EOT

The third and fourth characters will be a code number which corresponds to a diagnostic shown in Appendix G.

2.4 Additional Format Notes

2.4.1 Synchronous Communication

In synchronous communication, all blocks are preceded by 2 "SYNC" characters and followed by an LRC character.

The SYNC characters are defined in the ASCII Table in Appendix D. The LRC (Longitudinal Redundancy Check) is a simple "no-carry" addition of the characters in the block between and including SOH and EOT.

2.4.2 Parity

Under normal operation, the DATA LINK must receive and will transmit *odd* parity, for all characters, including the LRC.

The only exception to this is when operating under Terminal Option control. In this case, the DATA LINK will ignore incoming parity, but will continue to transmit *odd* parity.

2.5 Communication Signal Specifications

2.5.1 EIA RS232C Operation

When using the RS232C configuration, the DATA LINK "looks" like a data terminal. Therefore the connections to a data set (Modem) should be as shown below:

Modem		Data Link
Data Terminal Ready	←	Data Terminal Ready
Request To Send	←	Request To Send
Receive Data	←	Transmit Data
Data Set Ready	→	Data Set Ready
Clear To Send	→	Clear To Send
Transmit Data	→	Receive Data
Signal Ground	↔	Signal Ground

When connecting the DATA LINK to a data terminal, the connections should be as shown below:

Terminal		Data Link
Data Carrier Detect	←	
Data Set Ready	←	Data Terminal Ready
Clear To Send	←	Request To Send
Receive Data	←	Transmit Data
Data Terminal Ready	→	Data Set Ready
Request To Send	→	Clear To Send
Transmit Data	→	Receive Data
Signal Ground	↔	Signal Ground

Voltage levels, clock timing, etc., follow EIA RS232C specifications.

2.5.2 Differential Line Operation

When using a differential line for data transmission, the DATA LINK's "high" differential voltage threshold is +1.1 volts and the "low" threshold is -1.1 volts, for receiving.

> **NOTE**
>
> Differential voltage means the difference between the "receive data plus" line (pin number 14) and "receive data minus" (pin number 11). A differential voltage above +1.1 volts will be interpreted by the DATA LINK as a "mark" (logic "1"), and a differential voltage below -1.1 volts will be interpreted by the DATA LINK as a "space" (logic "0").

For transmitting, the DATA LINK will maintain a "high" threshold of +1.5 volts, and a "low" threshold of -1.5 volts, while sourcing or sinking a maximum of 40 milliamps respectively. Maximum common mode voltage permitted at the DATA LINK's receiver is ±15 volts, and maximum permissible input voltage is ±25 volts.

Regarding signal timing for synchronous operation, the DATA LINK can receive data which is set up a minimum of three microseconds before the nagative clock edge, and which is held for a minimum of three microseconds past the negative clock edge. Data transmitted by the DATA LINK will be available a minimum of two microseconds after the positive clock edge.

> **NOTE**
>
> These specifications refer to conditions at the connector of the DATA LINK and assume a user supplied differential clock.

Cabling should be shielded twisted pairs (6 twists per foot or equivalent) of at least 22 gauge wire (shielding is required on long local lines where the possibility exists that a difference in potential may be found in the remote power ground). The far end of the transmission line, at or near the DATA LINK, should be terminated in a 200 ohm load, 100 ohms to ground from each side of the line.

2.6 Programming

2.6.1 General

Using ASCII code, programming is in 5TI language, e.g. STR X100. Each letter, numeral, or space is represented by one ASCII character. The OP code (e.g. STR, AND, OR, etc.) should be separated from the I/O designator (e.g. X100, Y15, CR105, etc.) by one space (a unique ASCII character). Multiple OP codes (e.g. AND-NOT, OR-NOT, OR-STR, etc.) should be separated by dashes.

2.6.2 Timers and Counters

When programming timers and counters, the preset word must be preceded by a "pounds" sign (#), and the current word must be preceded by a "dollar" sign ($), and will be transmitted in this manner from the DATA LINK.

2.6.3 Command Character

The following characters are used as command characters:

a. W ..... Write to sequencer memory

b. R ..... Read from sequencer memory

c. I ..... Read from sequencer image register.

Appendix G contains some examples of programming sequences.

2.7 Terminal Option – Introduction

The terminal option for the DATA LINK/5TI system is intended to give the user a more sophisticated way in which to use the 5TI. By incorporating some "intelligence" into the DATA LINK, it is possible for the system to give the user some interactive access.

Below is a summary of the capability of each of the thirteen system commands. Format and usage will be explained in Section 2.7.1.

a. LIST – This command enables the DATA LINK, via the terminal printer to print out all (or part) of the sequencer memory. Output will be in the 5TI programming language, and the printout will be in consecutively numbered 8½" x 11" pages suitable for a ring binder, with a user supplied heading.

b. IR – The IR command allows the user to print out all (or part) of the image register.

c. EDIT – Allows editing of any sequencer location. The location is selected, and the DATA LINK responds by printing the current contents, followed by a comma. The user should then add the new entry.

d. SEARCH – The SEARCH command will enable the user to find, and print out, all uses of any I/O element (X,Y, or CR), or any OP code.

e. MONITOR – The MONITOR command gives the ability to comprehend any changes in up to twenty consecutive image register bits. The change in each (0 to 1, or 1 to 0) will be printed.

f. DELETE – Allows the user to selectively delete portions of memory and recompile the remaining memory.

g. INSERT – Allows the user to insert programs anywhere in memory.

h. CROSS REFERENCE – Allows the user to obtain a cross reference listing of all I/O functions and where they are used. The printout will be consecutively numbered 8½" x 11" pages suitable for a ring binder, with a user supplied heading.

i. CLEAR – Allows the user to selectively clear portions of memory to either zeros or ones.

j. SAVE – Use of the SAVE command allows recording on tape cassette, of the sequencer program. Verification of the tape will occur at the user's option.

k. LOAD – The LOAD command will cause a prerecorded sequencer program to be downloaded, from tape, to the sequencer memory. Verification of the sequencer memory will be at the user's option.

l. CHECK – The CHECK command will enable the user to find any differences between a prerecorded program on tape, and the present sequencer program. All discrepancies will be printed out.

m. BEGINNING – The BEGINNING command allows the user to return to the start-up portion of terminal option.

2.7.1 Format and Usage

This section describes, in detail, the format and usage of each of the commands incorporated in the terminal option of the DATA LINK.

2.7.2 Start Up

Initially, upon power up of the DATA LINK in the terminal option mode, the DATA LINK terminal software will make inquiries as to the status of the user's sequencer and terminal. These inquiries are concerned with the following areas:

1. Whether or not to return the line character.
2. Number of words in the sequencer memory.
3. Type of terminal being used.

In each case, the user must make appropriate responses via the keyboard.

The sequence of comments and questions is shown below. Acceptable user responses are also shown.

	System Message		Acceptable User Response(s)
1.	Echo back?	1.	a Y (see below) ↵ b N. ↵
2.	Sequencer memory size?	2.	(see below) ↵
3.	TI ASR 733?	3.	a Y (see below) ↵ b N. ↵
4.	*	4.	

Question 1's response should be a "yes" to retransmit the line character. An incorrect response will have no characters printed or two characters printed. The answer to Question 2 should reflect the user's actual working memory size and not the capacity of the sequencer. Question 3's response should be a "Y" (yes) only if the user is operating with a TI Model ASR 733. A positive response will allow the user access to three cassette-related system commands.

After the three responses have been made, the DATA LINK will enter the "STAR" mode. An asterisk will be printed. Whenever the user is in this mode, access to any of the system commands is possible. If, during the startup sequence, it is desired to return to the beginning, hit the ESC key.

The thirteen system commands are described below:

> **NOTE**
>
> All user inputs are shown in single quotation marks. All actual system responses are shown enclosed in double quotation marks.

2.7.3 LIST

	User Input	System Response
Complete Program Listing	1. 'LIST' ↵ 2. 'Y' ↵ 3. User inputs heading up to 40 characters, terminated by a carriage return (' ↵ ') 4.	1. "ALL?" 2. "HEADING:" 3. Prints all instructions located in sequencer memory 4. "*"
Partial Program Listing	1. 'LIST' ↵ 2. 'N' ↵ 3. 'aaaa,bbbb ↵ ' 4.	1. "ALL?" 2. "ADDRESS?" 3. Prints all instructions between locations aaaa, and bbbb, inclusive 4. "ADDRESS?"

At this point, the user can hit ESC (Escape Key) to exit the LIST mode, or the user can input two more memory addresses (see line 3, above).

> **NOTES**
>
> 1. Premature exit from LIST mode can be accomplished by hitting ESC key.
> 2. Addresses aaaa and bbbb are decimal representations of sequencer memory locations. They are a maximum of FIVE digits each. Leading zeros may be omitted.
> 3. aaaa must be less than bbbb.
> 4. Entry at the second or third words of a timer or counter instruction is permissible.

2.7.4 IR

Complete Image Register Listing	1. 'IR' ↵	1. "ALL?"
	2. 'Y' ↵	2. Prints all Image Register bits, with appropriate identification.
	3.	3. "*"
Partial Image Register Listing	1. 'IR' ↵	1. "ALL?"
	2. 'N' ↵	2. "WHICH?"
	3. 'Aaaaa, bbbb ↵'	3. Prints all Image Register bits of variable A(X,Y, or CR) from Aaaaa to Abbbb, inclusive
	4.	4. "WHICH?"

At this point the user can hit ESC to exit the IR mode. Alternatively, the user can input another variable and appropriate designators (see line 3, above).

NOTES

1. Premature exit of the IR mode can be accomplished by hitting the ESC key.
2. I/O designators aaaa, and bbbb are decimal numbers, a maximum of FIVE digits. They may contain leading zero's.
3. aaaa must be less than bbbb.

	User Input	System Response
	1. 'EDIT' ↵	1. "ADDRESS?"
	2. 'aaaa ↵'	2. Prints instruction located in aaaa, followed by a comma eg. "STR X240,"
To Modify	3a. Type new instruction (See Appendix II for acceptable instruction formats) Hit ' ↵ '	3a. Prints instruction located in next address Verifies current modification
To Examine Next Instruction	3b. Hit ' ↵ '	3b. Prints instruction located in next address. No change made to previous instruction.
To Exit the EDIT mode	3c. Hit 'ESC' key	3c. "*"

2.7.6 SEARCH

	User Input		System Response
1.	'SEARCH ↵'	1.	"OP CODE?"
2.	'Y ↵'	2.	"WHICH?"
3.	'zzz-zzz ↵'	3.	Prints all uses of the selected OP code and the locations in memory where used.
4.		4.	"WHICH?"
1.	'SEARCH ↵'	1.	"OP CODE?"
2.	'N ↵'	2.	"WHICH?"
3.	'Accc ↵'	3.	Prints all uses of the variable A, and the locations in memory where used.
4.		4.	"WHICH?"

At this point the user can input a new variable or hit ESC to exit to the STAR mode.

NOTES

1. A is either X, Y, or CR.
2. ccc is the I/O designator (decimal), with or without leading zeros.
3. zzz-zzz is any valid OP code only.
4. Premature exit can be accomplished by hitting ESC.
5. IF SEARCH is for timers or counters, the printout will include their preset and current words.

2.7.7 MONITOR

	User Input		System Response
1.	'MONITOR ↵'	1.	"WHICH?"
2.	'Accc,ddd ↵'	2.	Prints all changes of each of the variables Eg. "X244,0-1"

NOTES

1. At any point, the user can hit ESC to exit to the STAR mode.
2. A is either X, Y, or CR.
3. ccc and ddd are the I/O designators.
4. From one to twenty consecutive I/O's can be monitored.

2.7.8 DELETE

User Input	System Response
1. 'DELETE ↵'	1. "ADDRESS?"
2. 'aaaa,bbbb ↵'	2. Removes all memory from aaaa to bbbb inclusive, and extra memory spaces at the end are put in as JMP 0.
3.	3. "*"

2.7.9 INSERT

User Input	System Response
1. 'INSERT ↵'	1. "ADDRESS?"
2. 'aaaa ↵'	2. ":"
3. Type in new instruction ↵	3. ":"

At this point, the user can hit ESC to exit to the STAR mode or input another 5TI word.

NOTES

1. When a timer or counter is inserted, a total of three spaces are inserted so that the following two 5TI words must be the preset and current words.
2. 5TI words that are pushed off the end of the memory are lost.

2.7.10 CROSS REFERENCE

	User Input		System Response
1.	'CROSS REFERENCE ↵'	1.	"HEADING:"
2.	User inputs heading up to 40 characters '↵'	2.	Prints cross reference listing of all X's, Y's, and CR's used, in page format.
3.		3.	"*"

NOTE

1. Premature exit can be made by hitting ESC key.

2.7.11 CLEAR

	User Input		System Response
1.	'CLEAR↵'	1.	"ZEROs?"
2.	YES or NO Yes will clear with all zeros and No with all ones	2.	"ADDRESS?"
3.	'aaaa,bbbb↵'	3.	Clears all memory between aaaa and bbbb inclusive
4.		4.	"*"

NOTES

1. aaaa must be less than bbbb.
2. Premature exit can be made by hitting ESC key.

2.7.12 SAVE

	User Input	System Response
	1. 'SAVE ↵'	1. "READY TAPE – HIT RETURN"
	2. User must set up tape in Cassette 1 of 733 ASR and hit '↵'.	2. Sequencer memory is recorded onto tape
	3.	3. "CHECK?"
To check tape against sequencer memory	4a. 'Y' ↵	4a. Tape and sequencer memory are compared. Any discrepancies are printed.
	5.	5. "*"
To Exit SAVE Mode	4b. 'N' ↵	4b. "*"

NOTES

1. The user should refer to the Model 733 ASR operating instructions, TI Manual No. 959227-9701, Revision C, for correct us of the cassettes.
2. Premature exit from save can be made by hitting ESC key. Save will be aborted.
3. Before hitting return, tape must be rewound manually.
4. All switches on terminal must be set to "line" rather than "local."
5. The tape format switch must be set to "line" rather than "continuous."
6. The RDC option must be installed, turned on, and its switches set to "line."

2.7.13 LOAD

	User Input	System Response
	1. 'LOAD' ↵	1. "READY TAPE – HIT RETURN"
	2. The user must ready the tape in Cassette I and hit ' ↵ '.	2. Tape is downloaded to sequencer memory.
	3.	3. "CHECK?"
To check tape against sequencer memory	4a. 'Y' ↵	4a. Tape and sequencer are compared. Any discrepancies are printed.
	5.	5. "*"
To Exit LOAD Mode	4b. 'N' ↵	4b. "*"

NOTE

See above notes for SAVE.

2.7.14 CHECK

	User Input	System Response
	1. 'CHECK' ↵	1. "READY TAPE – HIT RETURN"
	2. The user must ready the tape in Cassette I and hit ' ↵ '	2. Tape and Sequencer memory are compared. Any discrepancies are printed.
	3.	3. "*"

NOTE

See above notes for SAVE.

2.7.15 BEGINNING

User Input	System Response
'BEGINNING ↵'	"ECHO BACK?" The system is now in start up. (see Par. 2.7.2)

2.7.16 Terminal Compatibility

The terminal option of the DATA LINK will be compatible with the TI model 733 ASR/ KSR data terminal, or similar machines. The communications interface is EIA-RS232C, at data rates up to 9600 baud, asynchronous.

> **NOTE**
>
> The TI 733 will operate at baud rates of 110, 150, and 300, with full printing capability.

For the non-cassette system commands the TI model 743 KSR will be a compatible data terminal.

When using the cassette system commands, a TI model 733 ASR with RDC option installed will be necessary.

2.7.17 Acceptable Sequencer Instruction Input Formats

The following list illustrates acceptable instruction formats for use in the EDIT and INSERT modes. All restrictions are defined at the end of this section.

a. Store Term:
   User Input: STR a Deeeee

b. Store Term Invert:
   User Input: STR b NOT a Deeeee

c. Jump:
   User Input: JMP a ggggg

d. Out:
   User Input: OUT a Feeeee

e. Out Invert:
   User Input: OUT b NOT a Deeeee

f. And:
   User Input: AND a Deeeee

g. And Invert:
   User Input: AND b NOT a Deeeee

h. Or:
   User Input: OR a Deeeee

i. Or Invert:
User Input: OR b NOT a Deeeee

j. And Store Term:
User Input: AND b STR a Deeeee

k. And Store Term Invert:
User Input: AND b STR b NOT a Deeeee

l. Or Store Term:
User Input: Or b STR a Deeeee

m. Or Store Term Invert:
User Input: OR b STR b NOT a Deeeee

n. Master Control Relay:
User Input: MCR a ggggg

o. Counter:
In 101 Sequencers – Count Up (only)
User Input: 1st Location: CTR a0
2nd Location: #M
3rd Location: $S

In 102 Sequencers – Count Up
User Input: 1st Location: CTR a0
2nd Location: #N
3rd Location: $T

In 102 Sequencers – Count Up/Down
User Input: 1st Location: CTR a 1
2nd Location: #N
3rd Location: $T

p. Timer:
In 101 Sequencers – (time increments of 0.1 seconds)
User Input: 1st Location: TMR a0
2nd Location: #P
3rd Location: $U

In 102 Sequencers – (time increments of 0.1 seconds)
User Input: 1st Location: TMR a0
2nd Location: #Q
3rd Location: $V

In 102 Sequencers – (time increments of 8.33 msec)
User Input: 1st Location: TMR a 1
2nd Location: #R
3rd Location: $W

2.7.18 Restrictions and Symbol Key

a. a ≙ one space character

b. b ≙ one hyphen

c. D ≙ X, Y, or CR

d. eeeee ≙ up to five digit decimal integer used as a designator for D (see above). Leading zeros are not required.

If D = X or Y, then $0 \leqslant eee \leqslant 255$
If D = CR, then $0 \leqslant eee \leqslant 511$

e. ggggg ≙ up to five digit decimal integer used as an operand for the jump instruction or MCR instruction. Leading zeros are not required. $0 \leqslant gggg \leqslant h$, where h is the number of sequencer memory locations.

f. F ≙ Y or CR

g. M, S ≙ up to five digit integers used as counts in 101 counter instruction, where $0 \leqslant M, S \leqslant 16383$.

h. N, T ≙ up to five digit integers used as counts in 102 counter instruction, where $0 \leqslant N, T \leqslant 32767$.

i. P, U ≙ up to five digit numbers that express the time in milliseconds, for a 101 timer instruction, where $0 \leqslant P, U \leqslant 16383$ milliseconds.

j. Q, V ≙ up to five digit numbers that express the time in milliseconds, for a 102 timer instruction, where $0 \leqslant Q, V \leqslant 32767$ milliseconds.

k. R, W ≙ up to five digit integers that express time in multiples of 8.33 millisecond, for a 102 timer instruction, where $0 \leqslant R, W \leqslant 32767$.

2.8 Troubleshooting

There are essentially three levels of troubleshooting in the DATA LINK. They are useful for both hardware and software diagnosis.

2.8.1 DC ON Light

With the circuit breaker in the "ON" position, the "DC ON" light should glow, signifying that the power supply is operating properly. If the "DC ON" light is not on, check:

a. Circuit Breaker Switch

b. Power Connections to DATA LINK

c. Power Source (e.g., 120 volt line)

2.8.2 Self Diagnostic

The self diagnostic feature is designed to perform a thorough test of the DATA LINK hardware. A special "loop back" connector is provided which is to be inserted into the EIA/differential port to run the test. In addition, the DATA LINK must be connected to an operating sequencer with READ/WRITE memory.

In running the test, the self diagnostic will use X254 and X255, CR508 through CR511, Y252 – Y255, and the first ten memory locations in the sequencer. It is therefore suggested that these not be used, if it is intended that the self diagnostic be used.

The sequence of operations is as follows:

a. Connect the DATA LINK and the sequencer.

b. Check to be sure memory locations 0-9 have been left blank, and that X254 and X255, Y252 through Y255, and CR508 through CR511 are not being used in the program in the sequencer.

c. Connect the "loopback" connector to the EIA/differential port.

d. Place three position switch in the "CPU" position.

> **NOTE**
>
> For synchronous, differential mode checkout, baud rate switches 1-4 must be set to open.

e. Turn AC power to sequencer to on.

f. Turn AC power to DATA LINK to on.

At this point, the self diagnostic will begin execution and will take approximately 60 seconds to run to completion. During its execution, the "DC ON" light will flash. If the diagnostic runs successfully, the light will cease flashing and remain on. If the self diagnostic fails, the light will go off.

> **NOTE**
>
> If "DC ON" light flashes for less than 50 seconds, more than 75 seconds, or at less than once per second, a failure is indicated.

2.8.3 NAKPAC

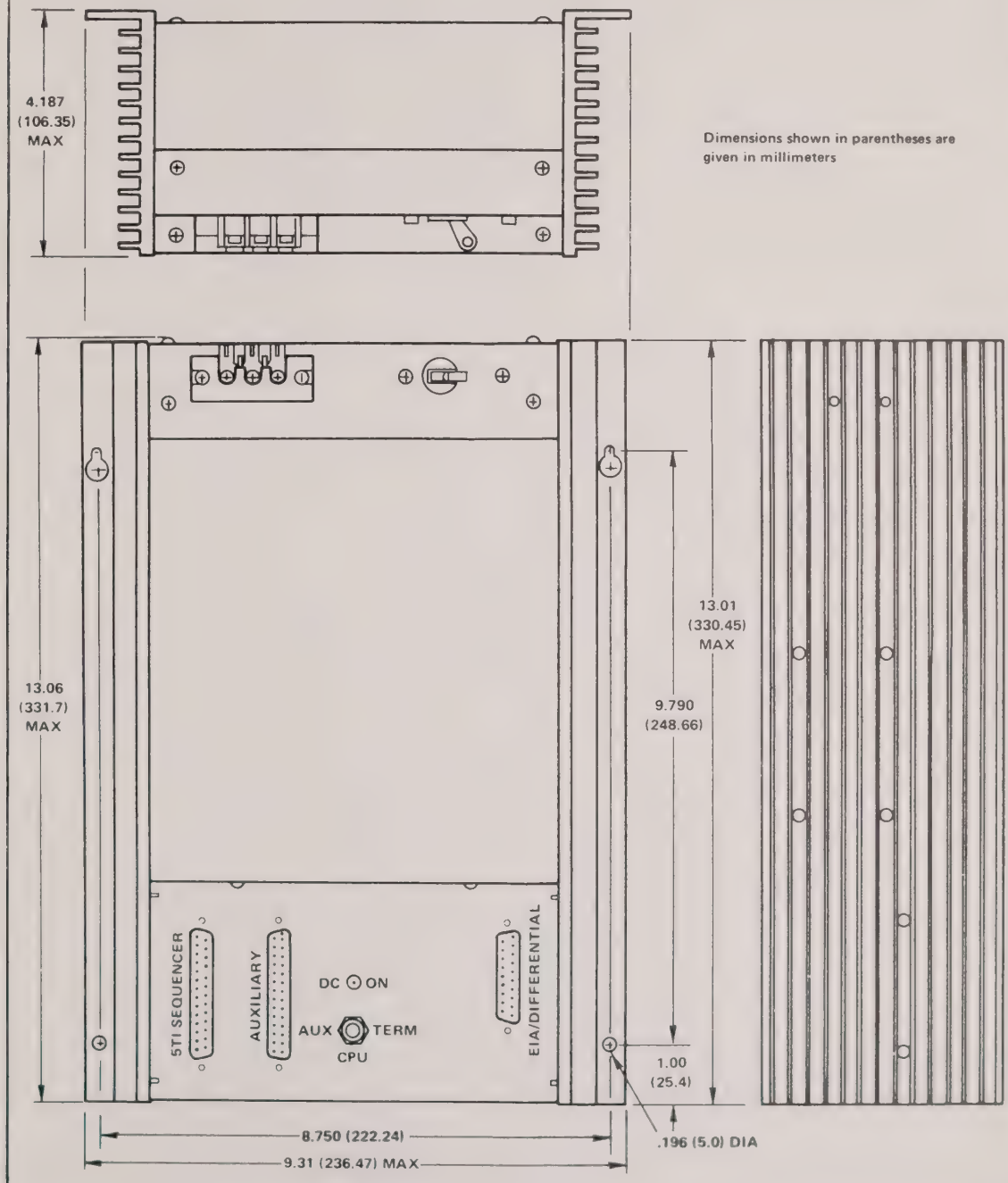
NAKPAC is a feature which is used to assist in diagnosing communication format caused errors such as illegal or missing characters, invalid commands, transfer errors, etc. It operates as follows.

If there are no errors in the transmission to the DATA LINK, it will respond with an "ACK", as explained in the section on programming.

However, if the transmission contains an error, a block will be transmitted back to the user as explained in Section 2.3.4.

APPENDIX A

DIMENSIONAL DRAWING



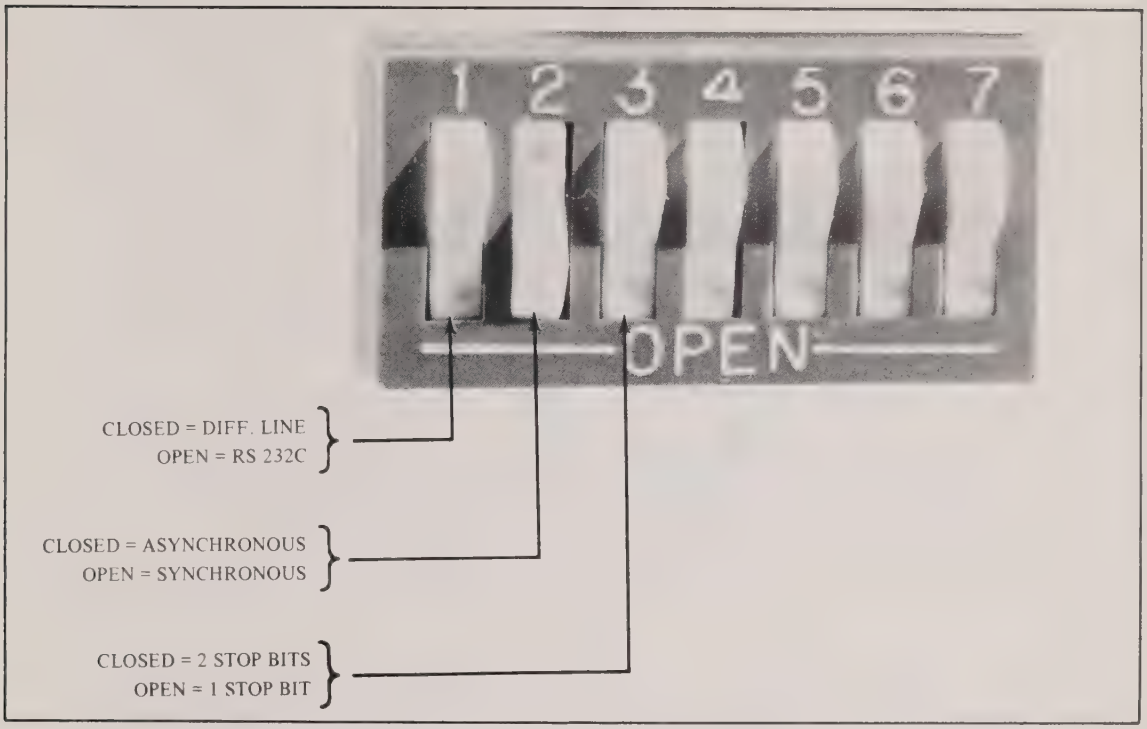
APPENDIX B

EIA/DIFFERENTIAL PIN ASSIGNMENTS

PIN NUMBER	RS232C	DIFF. LINE
1	Protective Ground	Protective Ground
2	Transmit Data	
3	Receive Data	
4	Request to Send	
5	Clear to Send	
6	Data Set Ready	
7	Signal Ground	
11		Receive Data (–)
13	Self-Diagnostic Ground	Self-Diagnostic Ground
14		Receive Data (+)
18		Transmit Data (+)
19		Transmit Data (–)
20	Data Terminal Ready	
23		Clock In (+)
24	Clock Out	
25		Clock In (–)

APPENDIX C

OPTION SELECTION DIAGRAMS



MULTIPOINT ADDRESS	SWITCH 4	5	6	7
SINGLE POINT	OPEN	OPEN	OPEN	OPEN
A	OPEN	OPEN	OPEN	CLOSED
B	OPEN	OPEN	CLOSED	OPEN
C	OPEN	OPEN	CLOSED	CLOSED
D	OPEN	CLOSED	OPEN	OPEN
E	OPEN	CLOSED	OPEN	CLOSED
F	OPEN	CLOSED	CLOSED	OPEN
G	OPEN	CLOSED	CLOSED	CLOSED
H	CLOSED	OPEN	OPEN	OPEN
I	CLOSED	OPEN	OPEN	CLOSED
J	CLOSED	OPEN	CLOSED	OPEN
K	CLOSED	OPEN	CLOSED	CLOSED
L	CLOSED	CLOSED	OPEN	OPEN
M	CLOSED	CLOSED	OPEN	CLOSED
N	CLOSED	CLOSED	CLOSED	OPEN
O	CLOSED	CLOSED	CLOSED	CLOSED

APPENDIX C

OPTION SELECTION DIAGRAMS
BAUD RATES

CPU SPEEDS		SWITCHES				TERMINAL SPEEDS	SWITCHES			
SYNC	ASYNC	1	2	3	4	ASYNC ONLY	5	6	7	8
1760	110	CLOSED	CLOSED	OPEN	OPEN	110	CLOSED	CLOSED	OPEN	OPEN
3200	200	CLOSED	CLOSED	CLOSED	OPEN	200	CLOSED	CLOSED	OPEN	CLOSED
4800	300	OPEN	CLOSED	CLOSED	OPEN	300	CLOSED	OPEN	OPEN	CLOSED
9600	600	OPEN	CLOSED	OPEN	OPEN	600	CLOSED	OPEN	OPEN	OPEN
	1200	CLOSED	OPEN	OPEN	CLOSED	1200	OPEN	CLOSED	CLOSED	OPEN
–	2400	CLOSED	OPEN	OPEN	OPEN	2400	OPEN	CLOSED	OPEN	OPEN
-	4800	OPEN	OPEN	OPEN	CLOSED	4800	OPEN	OPEN	CLOSED	OPEN
-	9600	OPEN	OPEN	OPEN	OPEN	9600	OPEN	OPEN	OPEN	OPEN
2400	150	OPEN	CLOSED	OPEN	CLOSED	150	CLOSED	OPEN	CLOSED	OPEN
1200	75	OPEN	OPEN	CLOSED	OPEN	75	OPEN	OPEN	OPEN	CLOSED
800	50	CLOSED	CLOSED	OPEN	CLOSED	50	CLOSED	CLOSED	CLOSED	OPEN
	1800	CLOSED	OPEN	CLOSED	OPEN	1800	OPEN	CLOSED	OPEN	CLOSED
	3600	OPEN	OPEN	CLOSED	CLOSED	3600	OPEN	OPEN	CLOSED	CLOSED
	900	CLOSED	OPEN	CLOSED	CLOSED	900	OPEN	CLOSED	CLOSED	CLOSED
2152	134.5	OPEN	CLOSED	CLOSED	CLOSED	134.5	CLOSED	OPEN	CLOSED	CLOSED

NOTE

When operating in a synchronous, differential mode, the first 4 baud rate switches should be "closed"

APPENDIX D

ASCII CODE SYSTEM AND CHARACTER SET

b_4 b_3 b_2 b_1	b_7→0, b_6→0, b_5→0	0 0 1	0 1 0	0 1 1	1 0 0	1 0 1	1 1 0	1 1 1
0 0 0 0		NUL	DLE	SPACE	0	@	P	`	p
0 0 0 1		SOH	DC1	!	1	A	Q	a	q
0 0 1 0		STX	DC2	"	2	B	R	b	r
0 0 1 1		ETX	DC3	#	3	C	S	c	s
0 1 0 0		EOT	DC4	$	4	D	T	d	t
0 1 0 1		ENQ	NAK	%	5	E	U	e	u
0 1 1 0		ACK	SYN	&	6	F	V	f	v
0 1 1 1		BEL	ETB	'	7	G	W	g	w
1 0 0 0		BS	CAN	(	8	H	X	h	x
1 0 0 1		HT	EM	)	9	I	Y	i	y
1 0 1 0		LF	SUB	*	:	J	Z	j	z
1 0 1 1		VT	ESC	+	;	K	[	k	{
1 1 0 0		FF	FS	,	<	L	\	l	|
1 1 0 1		CR	GS	-	=	M	]	m	}
1 1 1 0		SO	RS	.	>	N	^	n	~
1 1 1 1		SI	US	/	?	O	_	o	DEL

PRINTABLE CHARACTER

PRINTER CONTROL CHARACTER

AUXILIARY DEVICE CONTROL CHARACTER

CODES GENERATED BY KEYBOARD, BUT NO ACTION TAKEN

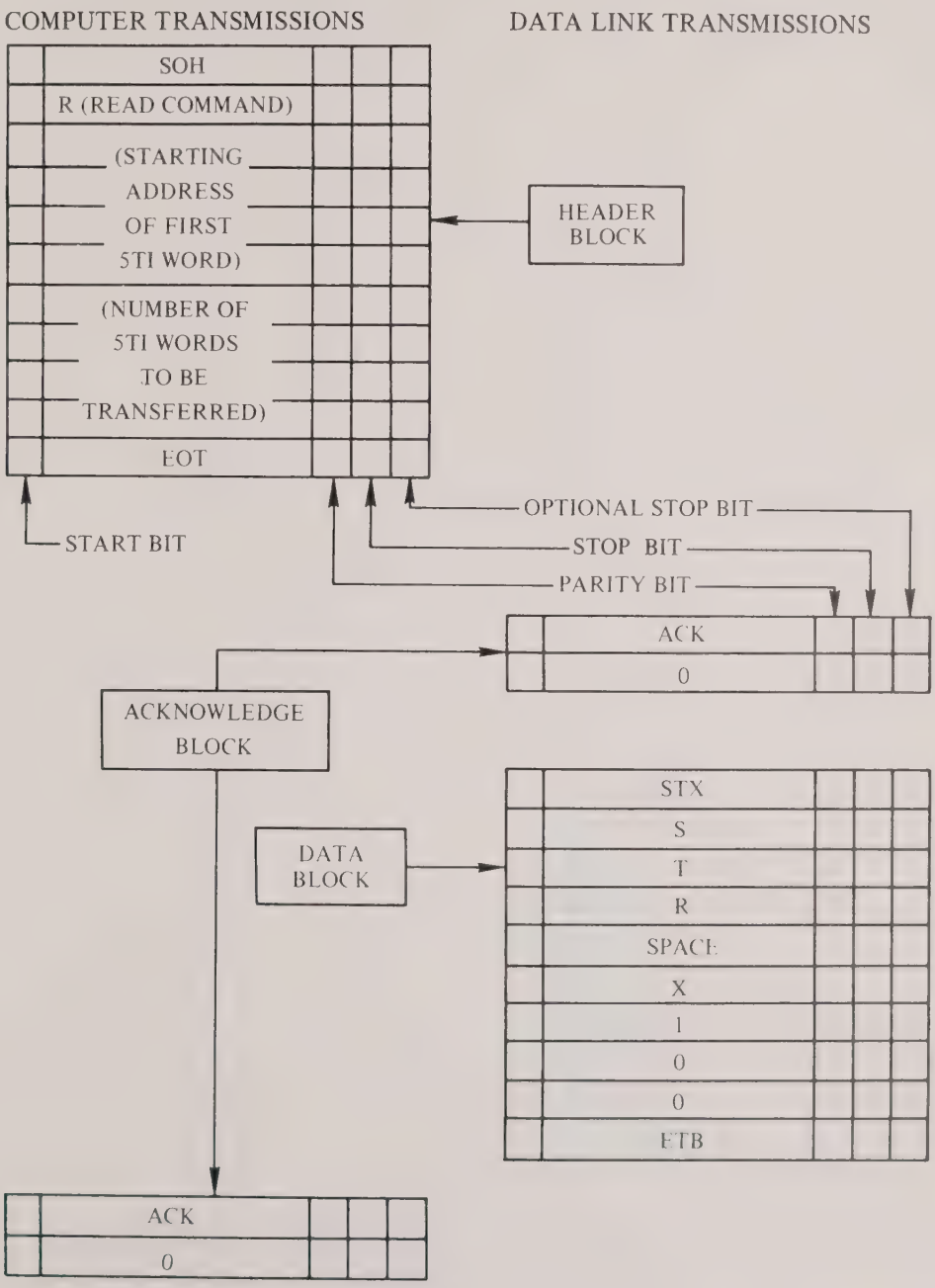
USASCII CONTROL CHARACTERS
(From USA Standards Institute Publication X3.4 1968)

ACK	acknowledge	ETX	end of text
BEL	bell	FF	form feed
BS	backspace	FS	file separator
CAN	cancel	GS	group separator
CR	carriage return	HT	horizontal tabulation
DC1 = X-ON	device control 1	LF	line feed
DC2 = TAPE	device control 2	NAK	negative acknowledge
DC3 = X-OFF	device control 3	NUL	null
DC4 = TAPE	device control 4 (stop)	RS	record separator
*DEL = RUB OUT	delete	SI	shift in
DLE	data link escape	SO	shift out
EM	end of medium	SOH	start of heading
ENQ = WRU	enquiry	STX	start of text
EOT	end of transmission	SUB	substitute
ESC	escape	SYN	synchronous idle
ETB	end of transmission block	US	unit separator
		VT	vertical tabulation

* not strictly a control character

APPENDIX E

EXAMPLES OF COMMUNICATIONS FORMAT
A. MEMORY READ – ASYNCHRONOUS



APPENDIX E

EXAMPLES OF COMMUNICATION FORMAT

B. MEMORY WRITE – ASYNCHRONOUS

COMPUTER TRANSMISSIONS

SOH
W (WRITE COMMAND)
(STARTING ADDRESS OF FIRST 5TI WORD)
(NUMBER OF 5TI WORDS TO BE TRANSFERRED)
ETB

START BIT

DATA LINK TRANSMISSIONS

OPTIONAL STOP BIT

STOP BIT

PARITY BIT

ACK
0

START BIT

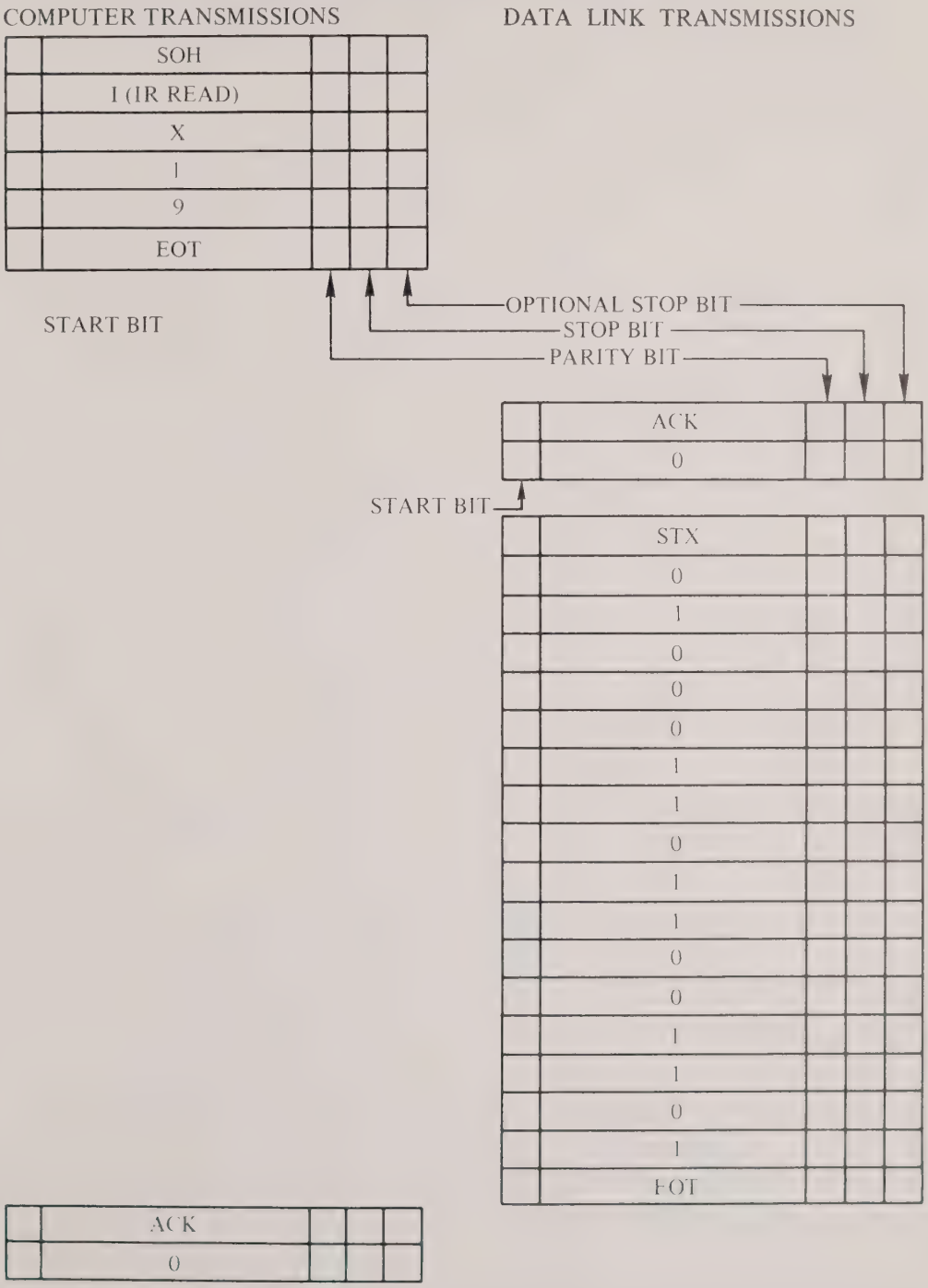
STX
S
T
R
SPACE
X
1
0
0
ETB

ACK
1

APPENDIX E

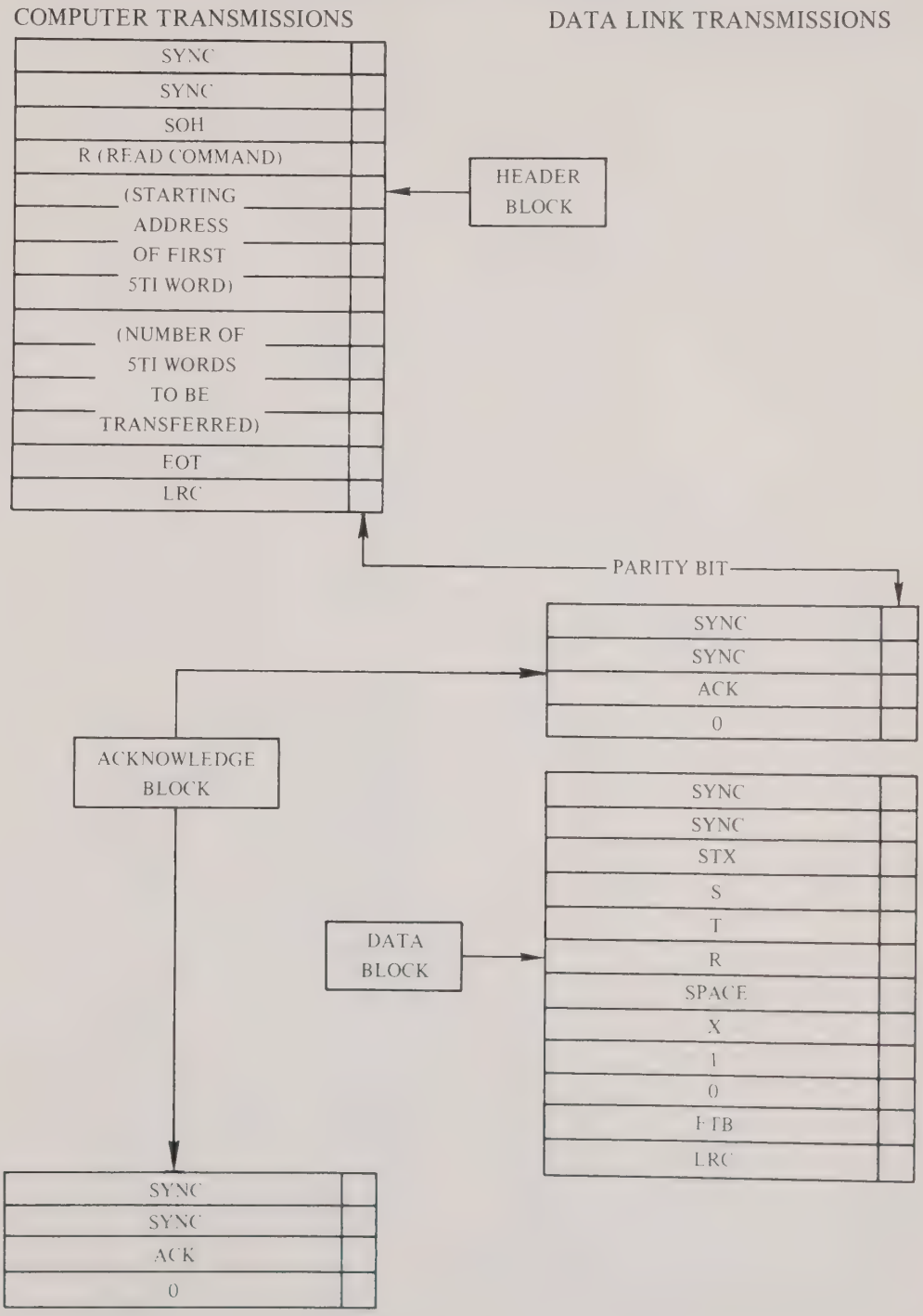
EXAMPLES OF COMMUNICATIONS FORMAT

C. IMAGE REGISTER READ – ASYNCHRONOUS



APPENDIX E

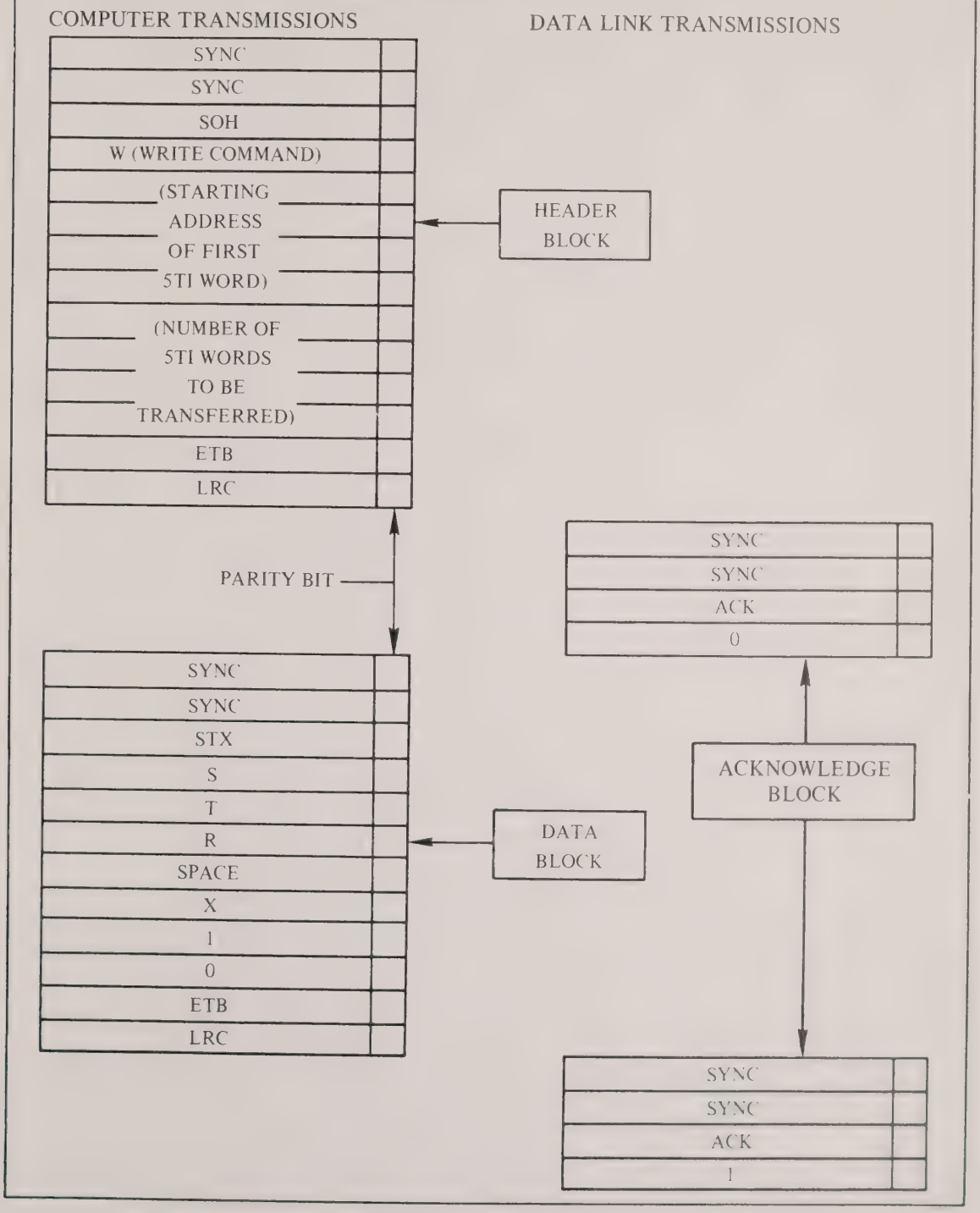
EXAMPLES OF COMMUNICATIONS FORMAT
D. MEMORY READ – SYNCHRONOUS



APPENDIX E

EXAMPLES OF COMMUNICATIONS FORMAT

E. MEMORY WRITE – SYNCHRONOUS



APPENDIX E

EXAMPLES OF COMMUNICATIONS FORMAT
F. IMAGE REGISTER READ – SYNCHRONOUS

COMPUTER TRANSMISSIONS

SYNC	
SYNC	
SOH	
I (I/R READ)	
X	
1	
9	
EOT	
LRC	

PARITY BIT

DATA LINK TRANSMISSIONS

PARITY BIT

SYNC	
SYNC	
ACK	
0	

SYNC	
SYNC	
STX	
0	
1	
0	
1	
1	
0	
0	
1	
1	
0	
1	
0	
1	
1	
1	
1	
EOT	
LRC	

F. IMAGE REGISTER READ – SYNCHRONOUS (CONTINUED)

COMPUTER TRANSMISSIONS	DATA LINK TRANSMISSIONS
SYNC	
SYNC	
ACK	
0	

APPENDIX E

EXAMPLES OF COMMUNICATIONS FORMAT
G. MULTIPOINT ADDRESSING

THE ONLY CHANGE TO THE COMMUNICATIONS FORMATS ALREADY PRESENTED IS IN THE HEADER BLOCKS. THEY SHOULD BE AS SHOWN BELOW FOR MEMORY READ OR WRITE.

SYNCHRONOUS

SYNC	
SYNC	
EOT	
(ADDRESS)	
SOH	
(R/W (COMMAND)	
(STARTING	
ADDRESS	
OF FIRST	
5TI WORD)	
(NUMBER OF	
5TI WORDS	
TO BE	
TRANSFERRED)	
EOT/ETB	
LRC	

ASYNCHRONOUS

	EOT		
	ADDRESS		
	SOH		
	(R/W (COMMAND)		
	STARTING		
	ADDRESS		
	OF FIRST		
	5TI WORD)		
	(NUMBER OF		
	5TI WORDS		
	TO BE		
	TRANSFERRED)		
	EOT/ETB		

AS INDICATED IN APPENDIX D, THE ADDRESS CHARACTER SHOULD BE AN ASCII CHARACTER

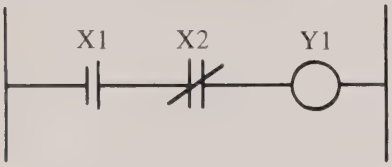
A THROUGH O

APPENDIX F

PROGRAMMING EXAMPLES

EXAMPLE 1

LADDER DIAGRAM



5TI PROGRAM

```
STR X1
AND NOT X2
OUT Y1
```

TO PROGRAM THE ABOVE VIA A DATA LINK INTO A 5TI SEQUENCER, THE FOLLOWING TRANSMISSION IS REQUIRED FOR ASYNCHRONOUS PROTOCOL WITH ONE STOP BIT.

COMPUTER TRANSMISSIONS

	SOH		
	W		
	0		
	0		
	0		
	0		
	0		
	0		
	0		
	3		
	ETB		

DATA LINK TRANSMISSIONS

	ACK		
	0		

CONTINUED ON NEXT PAGE

EXAMPLE 1 CONTINUED

COMPUTER TRANSMISSIONS

	STX		
	S		
	T		
	R		
	SPACE		
	X		
	1		
	ETB		

DATA LINK TRANSMISSIONS

	ACK		
	1		

	STX		
	A		
	N		
	D		
	–		
	N		
	O		
	T		
	SPACE		
	X		
	2		
	ETB		

	ACK		
	0		

CONTINUED ON NEXT PAGE

EXAMPLE 1 CONTINUED

COMPUTER TRANSMISSIONS

	STX		
	O		
	U		
	T		
	SPACE		
	Y		
	1		
	EOT		

DATA LINK TRANSMISSIONS

	ACK		
	1		

EXAMPLE 2

TO . . . . . READ IMAGE REGISTER BITS X12-X16, FROM DATA LINK "F" IN A MULTIPOINT ASYNCHRONOUS NETWORK, USING ONE STOP BIT:

COMPUTER TRANSMISSIONS

	EOT		
	F		
	SOH		
	I		
	X		
	1		
	6		
	EOT		

DATA LINK TRANSMISSIONS

	ACK		
	0		

CONTINUED ON NEXT PAGE

EXAMPLE 2 CONTINUED

COMPUTER TRANSMISSIONS

	ACK		
	0		

DATA LINK TRANSMISSIONS

	STX		
	0		
	1		
	1		
	1		
	0		
	1		
	0		
	0		
	1		
	0		
	0		
	0		
	1		
	0		
	1		
	1		
	EOT		

APPENDIX G

NAKPAC ERROR MESSAGES

Error Code	Cause	Explanation And/Or Remedy
NAK	Parity, Framing, Overrun Error, or Bad LRC.	1. Use Odd Parity. 2. Use Correct Number of Stop Bits. 3. Be Sure to wait for ACK Between Transmissions. 4. Use "HALF ADD" LRC.
	The remaining error messages will be transmitted as a block. The first two characters in the block will be "STX" and "?". Next the error code, a two digit number as shown below. Finally, the block will be terminated by an "EOT".	
00	Incorrect ACK Phase.	The DATA LINK Received Two Consecutive ACK 0's or ACK 1's, Meaning A Data Block Was Lost. Retransmit Record.
01	Wrong Terminator Character on Header Block.	The Header Block was Received With No EOT or ETB Terminator Character. Retransmit Header Block.
02	Sequencer Word Read is Not Word Written.	The Communication Between the DATA LINK and Sequencer was Unsuccessful. Retransmit Data.
03	Incorrect Write Data Block Terminator Character.	Make Sure the Data Blocks End in ETB or EOT. (Use EOT on the Last Block Sent, ETB on Others.)
04	Sequencer Time Out.	Check Cable to Sequencer, Sequencer Power, "START UP/RUN" Switch in "RUN".
05	Header Block Command Character Incorrect.	Only Three Command Characters are Valid: W = Write Memory R = Read Memory I = Read Image Register
06	Receive a NAK For No Discernible Reason.	The DATA LINK Received a NAK While in Idle Mode.

Error Code	Cause	Explanation And/Or Remedy
07	Received a STX For No Discernible Reason.	The DATA LINK Received a STX Character While in the Idle Mode.
08	5TI OP Code has Incorrect Number of Alpha Characters.	
09	Invalid Character in a Write Data Block.	Non-Alphanumeric Character in Write Data Block.
10	Header Block Word Count, and/or Beginning Address Invalid.	1. Invalid Starting Address, e.g. 1100 2. Number of Words to be Written is Either Less Than 1, or Greater Than 1024. 3. The Starting Address Plus the Number of Words to be Written Results in an Invalid Memory Location.
11	Image Register Read Command Block Contained Invalid Character.	Character in Image Register Read Header Block Must be Either X, Y, or CR.
12	Image Register Type Number Exceeded Limit.	A Number Larger Than 225, for an X or Y, or Larger Than 511, for a CR, was Transmitted.
13	Received Too Many OP Codes in Write Data Block.	The Maximum Number of OP Codes in a Combination is Three; e.g. OR-STR-NOT.
14	OP Code Followed by Invalid Character.	
15	OP Code Not Followed by X,Y, or CR, or C Not Followed by R.	
16	Number Value Too Large	Write Data Block Contained a Number Greater Than 225 for an X or Y, 511 for a CR, or 32768 for a Timer or Counter Value.
17	Invalid OP Code.	Operation Code Not one Defined in 5TI Language. Check Spelling.
18	Invalid Number.	
19	No EOT on Image Register Read Command Block.	The DATA LINK Received an Image Register Read Header Block with an ETB Terminator Character.
20	Number Field Exceeded.	The DATA LINK Received More than Five Digits in a Number Field.
21	Time Out.	Extended interruption of communications.

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INDUSTRIAL CONTROLS
PUBLICATION 748

PRINTED IN U.S.A. 2/78 1K